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The importance of Liquefied Natural Gas in global energy market through shipping transportation

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Important keywords: Energy, Liquefied Natural Gas, Shipping

Abstract

The Liquefied Natural Gas market tends to grow rapidly at a global level. It is clear that the LNG market will play a significant role in tomorrow's energy market as both gas and renewable energy sources are becoming the strongest growing energy segments in the years to come. At the same time, fossil fuel use should be constrained until the next decade. Environmental goals could be achieved if a specific amount of coal were displaced by gas, as among fossil fuels, natural gas is the cleanest one. Natural gas covers 25 percent of the world's energy needs, of which 10% is supplied as LNG. To summarize, the role of pipeline gas has been reduced over the last decades, due to a number of financial and geopolitical issues. On the other hand, LNG is the solution to the above situation as it is a form of condensed ecological energy and, thanks to its properties; LNG is able to be transported easily from continent to continent. Last but not least, this form of energy carrier is commonly accepted.

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Chapter 1: Introduction

Objective and Scope of Work

This brief introductory chapter explains the motivation and general content of this thesis about the importance of Liquefied Natural Gas in the global energy market through shipping transportation.

It is clear that energy plays a vital role in human wellbeing and affects, in a crucial way, the global economy and the nation's development. The strongest motivation for the research in this thesis was the extreme development of LNG trade among markets and, of course, LNG's growing role in the world energy scene, as the most efficient alternative natural gas supply source.

The aim of this thesis is to analyze the importance of LNG in the global economy and more specifically, in the economies of the states that are the main LNG terminals. Also, the thesis will examine the trade relations among LNG exporting nations and importers from the scope of shipping transportation. During the effort to accomplish this research, it followed the methodology of a literature review.

The thesis is structured in six different chapters:

The second chapter begins with a brief introduction to natural gas and then moves on to an analysis of LNG. Therefore, these individual energy forms are analyzed and presented, giving importance to the obstacles that LNG has to overcome, such as transportation and geopolitical issues. The other main part of this chapter is a literature review with a focus on the LNG supply chain and its value chain.

The third chapter is dedicated to the description of international LNG trade between importing and exporting nations. It starts with the main LNG importers and continues with the most important exporting nations, such as Russia. The last section of this chapter presents the largest LNG trade flow routes in the energy world.

In the fourth part of the thesis, detailed emphasis is given on LNG terminals all over the world and the functions of them. The activity at the LNG terminal consists of four main stages. First of all, the receiving and unloading of LNG from ships, then the storage or tanking of LNG, the compression and regasification and the final stage which has to do with transmission. The fifth chapter deals with LNG pricing. Firstly, it analyzes the different price formation mechanisms, especially the Oil Price Escalation (OPE) and the Gas-on-Gas Competition (GOG). This chapter ends up with the analysis of different gas pricing methods among markets and how these methods affect the global prices.

As far as the last chapter of this thesis, it delves into the shipping sector and how LNG is able to grow rapidly thanks to shipping. Initially, the 6.2 section presents a historical context of the LNG fleet, and in the 6.3 section, the active LNG fleet is analyzed at a global level. In the next section of this chapter, it is perceived that liquefied natural gas as a marine fuel is a potential solution with significant benefits. In the conclusions, the results are further discussed with insight for further research.

To sum up, the contribution of this thesis is to analyze the evolution of LNG and its perspectives in global markets, especially in the European one. Moreover, it will underline the crucial importance of trade relations in maritime zones, so that nations can overcome the obstacles of natural gas transportation from continent to continent.

Chapter 2: Analyzing LNG

2.1 Introduction

Natural gas possesses the first place as the fastest growing energy resource in global energy markets for more than twenty years, driven by the low greenhouse gas emissions as well as high conversion efficiency in power generation. Natural gas used to be transported exclusively via pipelines. Despite the fact that pipelines have the ability to supply with security and stability large gas amounts, there are some serious obstacles. Attention has shifted to a more efficient way to transfer natural gas and this is its liquefaction and its transport via marine sector. In this way, the security of energy supply of many consuming countries has been improved and the geopolitical and political constraints on global gas supply have been reduced.

As far as the LNG supply chains, they have diversified and introduced competition into markets, which previously "captured" by pipeline gas suppliers. Energy firms have invested in a number of various facilities that are closely interconnected and reliant on one another in order to make LNG accessible for usage in a market. There are two main different kinds of supply chains, the first one is the traditional LNG supply chain and the other being the FPSO LNG supply chain. What is more, this section studies the value chain of LNG and its components.

This chapter briefly summarizes the vital importance of liquefied natural gas (LNG) development as the unique way to overcome the obstacles of natural gas transportation through pipelines.

2.2 What Is Natural Gas?

Natural gas is made up of hydrocarbon gas mixtures, primarily methane, but also ethane, butane, propane, and other naturally occurring hydrocarbons. Natural gas reserves are found deep under the ground, near other solid and liquid hydrocarbon deposits such as coal and crude oil.

Natural Gas is one of the three main forms of fossil fuel in the world, along with coal and petroleum. As far as natural gas is concerned the fossil fuel with the most limited carbon density and the least carbon dioxide (per unit energy) emits. In contast with other forms of fossil fuels like coal and oil, natural gas is a more sustainable choice as the rates of global warming emissions from its combustion are much lower. Natural gas emits approximately the half of carbon dioxide when combusted in a new power plant than a typical coal plant.

All the above, enabled natural gas to penetrate effectively in the industrial market as it is essential to develop “clean” energy sources in order to protect the global energy supply safety and decrease the global climate change.

Nations with the most significant natural gas reserves such as Russia, Qatar and Iran want to enlarge their shares in energy supply in order to derive benefit from the advantages of natural gas. The same time other countries need to import amounts of natural gas in order to cover their energy needs (Esen & Oral, 2016)

Traditionally, natural gas transported from producers to consuming nations via pipelines. The economic and geopolitical aspect of these trade posses the most significant role. The delivery of gas to western European nations from Russia and the Caspian area is an excellent illustration of pipeline transport and its complexity, especially when natural gas must pass through many countries before reaching its final destination. (Gkonis & Psaraftis , 2019)

In this point the LNG technology is an alternative and direct way to transport natural gas by sea without passing through third countries.

2.3 What is LNG?

Growing global energy consumption, rising oil costs, dwindling oil supplies, and the benefits of lower greenhouse gas emissions from natural gas combustion are all promoting LNG's acceptance and demand.

Liquefied natural gas (LNG) is natural gas that has been converted to a liquid form. Natural gas is cooled to approximately -260 degrees Fahrenheit, creating a clear, colorless, and non-toxic liquid. This method, which was invented in the nineteenth century, allows natural gas to be transported to areas where pipelines do not reach. Where pipelines of natural gas are not practical or do not exist, liquefying natural gas is one means of transferring natural gas to the markets. Natural gas is 1/600th of its space in its liquid condition, which means that natural gas is down 600 times, making shipping and storage considerably easier.

This view makes natural gas thick and simpler to carry through vessels and vehicles. This transportability comfort can contribute to addressing the challenge of natural gas transport. Since numerous storage facilities are sometimes located at distant offshore sites, there would need to be extensive pipes underwater in order to provide natural gas for consumption and storage. According to Barbe and Riker (2015), In comparison with pipeline gas, LNG becomes economically attractive in case of a long distance transportation. On the one side it is clear that gas pipelines are more desirable for short distances, on the other side Vast-distance routes, especially when crossing oceans, or long expanses of water, are competitive, because building costs for undersea networks are prohibitive. LNG is economically viable when the offshore gas pipeline reaches less than 700 miles and the breakdown point for onshore gas is around 2.200 miles. As far as off shore gas is concerned.

Last but not least, LNG has numerous important environmental benefits. Because of the nucleation particles, clean LNG burning produces almost little particulate pollution. In addition, LNG emits less gaseous emissions than other types of fossil fuels, such as carbon dioxide (CO2) and nitrogen oxides (NOX). Furthermore, due to the pretreatment process, which eliminates the majority of the sulfur content in the natural gas, regasified LNG emits very little sulfur oxides (SOX).

2.4 LNG supply chains

The following components make up LNG supply chains: Supply networks for LNG Businesses in the energy sector, transportation corporations, storage companies, and, of course, governments are all involved.

An integrated and broad supply chain, with a range of various facilities linked to one another, is required to transport LNG from the point of origin to the ultimate customer. In theory, two types of LNG supply networks may be distinguished: the traditional LNG supply chain and the FPSO LNG supply chain. (Al-Haidous & Al-Ansari, 2019).

> 2.4.1) The traditional LNG supply chain can be divided into four main activities: gas exploration, liquefaction, transportation and regasification.
>
> The initial stage of traditional supply chain is formed by the gas fields from which natural gas is extracted. From the onshore or off-shore gas fields, the gas is transported via pipelines to the liquefaction plant, where there the gas is processed and LNG is produced. Usually, before it is liquefied, natural gas is routed through a Natural Gas Liquid (NGL) recovery unit. The NGL components that are recovered from the natural gas, are valuable and can be sold separately to the market. There are some main types of natural gas liquids and many different applications for NGL products. After this process, the remaining lean gas is liquefied, as a result we have the product LNG.
>
> The next stage in this form of supply chain is the storage of LNG and the transportation to the importing countries. Transportation of LNG from the liquefaction plant to the regasification facilities can be performed by different means of transportation like ships or trucks. Specialised ships are used for the transport of LNG, with tanks that are double-hulled and insulated. The tanks are designed to keep the cargo at a cryogenic temperature (-169 ^{o}C) during transport. Carriers are used for the transportation overseas to importers that are located close to the coast. However, if customers of LNG are situated in an area that cannot be reached by ship, trucks are the only viable option. As far as a typical LNG truck, it also contains a cryogenic tank. Once the LNG has reached the importing countries, it is offloaded to a regasification plant. At the receiving terminal, the LNG is, through the regasification process, transformed

back to natural gas, which is then pumped into the already existing gas distribution network to end consumers. The regasification plants can be both offshore and onshore. Regarding to offshore units that are gaining in importance are Floating Storage and Regasification Units The natural gas is transported to the mainland via subsea pipelines. At onshore terminals, carriers are unloaded using ship pumps, after which it is stored and regasified.

2.4.2) Whereas, a Floating Production Storage and Offloading (FPSO) installation is a floating facility. In this kind of supply chain, gas is recovered from offshore gas fields by and processed on (FPSO) units. The floating production, storage and offloading system for liquefied natural gas (LNG-FPSO), is a new conceptual unit and an effective and realistic way for exploitation, recovery, storage, transportation and end-use applications of marginal gas fields and offshore associated-gas resources. However, a real LNG-FPSO unit cannot be built unless some breakthroughs in many key technologies are produced. Many unique characteristics of LNG-FPSO, such as restricted space, platform motion, LNG sloshing in inner storage tank and offloading system, which have not been considered in the onshore projects, are the most rigorous factors to be taken into account during design. (Wang et al., 2008)

2.5 The Value Chain

A Liquefied Natural Gas value chain consists of four main components:

1) Exploration and production: natural gas exploitation is a very high risk and cost endeavor. Exploring natural gas resources. Natural gas is usually discovered when seeking petroleum. Exploration and production activities cover fresh deposition for hydrocarbon reserves, exploration, boiling and assessment.
2) Liquefaction: The cost related to liquefaction process is about technologies applied and investment in terminals. The feed gas reaches to the liquefaction plant from the field of production. The contaminants found in natural gas which produced are removed to avoid freezing up and damaging equipment

when the gas is cooled to a temperature -161oC. Also, the gas is filtered of all impurities and is ready to meet pipeline specifications at the delivery point. After that, starts the liquefaction process by the use of refrigerants. By liquefying the gas, it’s volume reduced by a factor of 600, which means that LNG in -161^{o}C uses 1/600th of the space required for a comparable amount of natural gas at room temperature and atmospheric pressure.

3) Shipping: the transportation costs are logistics costs. LNG tankers are double-hulled ships specially designed and insulated to prevent leakage or rupture in case of an accident. A tanker ship with temperature-controlled tanks which are intended to transport Liquefied Natural Gas (LNG), is termed as LNG tanker or LNG Ship. These vessels, unlike other tankers, have a propulsion system which is fueled with natural gas, thus, emitting lesser greenhouse gases.

   These tankers should be capable of bearing high pressure and the temperature inside these tankers should be maintained at about -163˚C. As the LNG gas is to be transported in its liquid form, it must be transported in vessels having the high-pressure bearing capacity and lower inner temperature. As per the requirement of LNG ships, these can be of three types namely:

- completely pressurized
- both pressurized and refrigerated
- and completely refrigerated

4) Storage and re-gasification: In order to return the liquid natural gas into a gaseous form. The Liquefied Natural Gas is pumped via several components of the terminal to a doubles-walled storage tank, which is heated in a controlled atmosphere, at atmospheric pressure and then pumped at high pressure. The LNG is warmed and the vaporized gas is then regulated for pressure and enters the pipeline system as natural gas. Finally, this natural gas delivered by local gas utilities to consumers in the form of electricity.

Just like oil projects, LNG projects have high capital intensity. Costs of large projects can rise to billions of dollars. In achieving cost reductions, economies of scale play a significant role. The most dynamic cost of the above is the transport cost. Transport costs constitute an important component of LNG purchasing costs. Transportation refers to four cost positions. They include rental costs of methane carriers, fuel costs, harbor fees and charges associated with freight by sea. (Lee et al., 2017)

Fees of rental of methane carries are strongly depended on two factors: a) the economic situation of natural gas markets, which is tightly linked with the global economic situation and b) the supply of LNG fleet in the world. An additional cost driver is the price paid for fuel. Lower fuel prices could reduce the operating costs. Furthermore, harbor tariffs and charges for sea transportation conclude transportation costs too.

2.6 Conclusions

The preceding chapter attempts to describe the factors that led to the requirement for LNG development as the most appropriate solution to the hurdles that natural gas must overcome while transiting through pipelines. Furthermore, LNG is accompanied by a number of advantages, such as environmental benefits, which is exemplified well by the example of a natural gas pipeline.

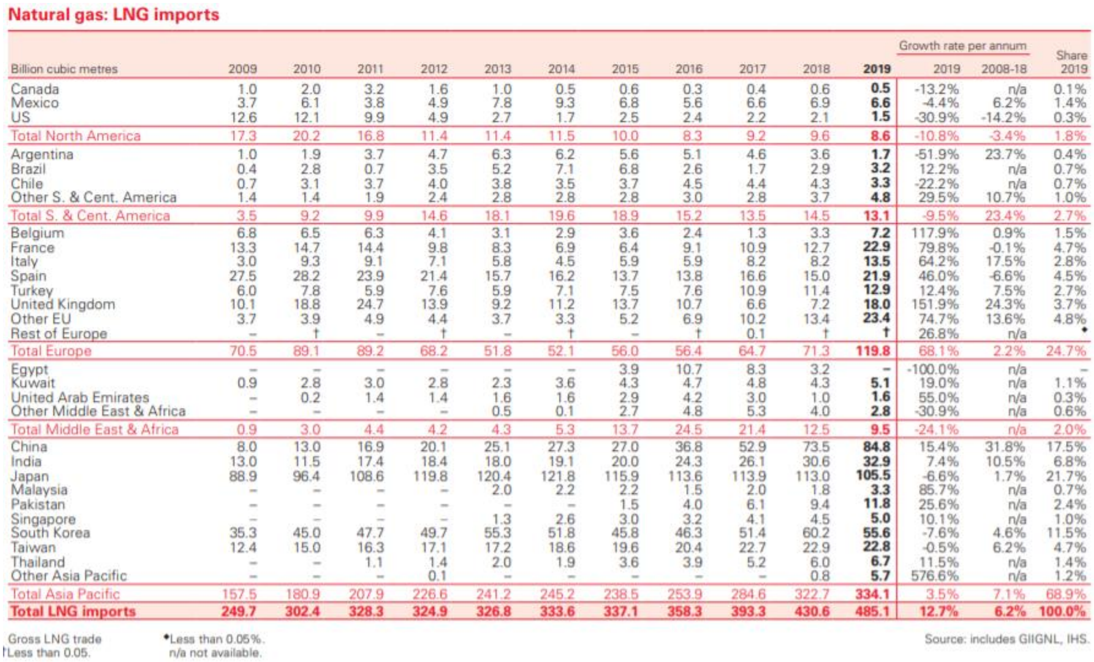
Chapter 3: LNG Trade

3.1 Introduction

The third section delves into LNG imports and exports that constitute the international LNG trade. Initially, it compares the status of the LNG importing markets in a globall level from 2009 until today according to BP statistical review of world energy in 2020. In the second part, LNG exports are summarized by country from 2009 to 2019. Finally, it presents the largest global LNG trade flow routes. LNG trade continues to show an important growth all over the world over the past years. Such growth and diversification will create requirements for huge capital investments throughout LNG supply chains. This situation accompanied by risks and opportunities that industry has to deal with them.

3.2 LNG Imports:

Table 1: LNG Imports by Nation from 2009 to 2019



Natural gas: LNG imports

												Growth rate per annum		Share
Billion cubic metres	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	**2019**	2019	2008-18	2019
Canada	1.0	2.0	3.2	1.6	1.0	0.5	0.6	0.3	0.4	0.6	**0.5**	-13.2%	n/a	0.1%
Mexico	3.7	6.1	3.8	4.9	7.8	9.3	6.8	5.6	6.6	6.9	**6.6**	-4.4%	6.2%	1.4%
US	12.6	12.1	9.9	4.9	2.7	1.7	2.5	2.4	2.2	2.1	**1.5**	-30.9%	-14.2%	0.3%
Total North America	17.3	20.2	16.8	11.4	11.4	11.5	10.0	8.3	9.2	9.6	**8.6**	-10.8%	-3.4%	1.8%
Argentina	1.0	1.9	3.7	4.7	6.3	6.2	5.6	5.1	4.6	3.6	**1.7**	-51.9%	23.7%	0.4%
Brazil	0.4	2.8	0.7	3.5	5.2	7.1	6.8	2.6	1.7	2.9	**3.2**	12.2%	n/a	0.7%
Chile	0.7	3.1	3.7	4.0	3.8	3.5	3.7	4.5	4.4	4.3	**3.3**	-22.2%	n/a	0.7%
Other S. & Cent. America	1.4	1.4	1.9	2.4	2.8	2.8	2.8	3.0	2.8	3.7	**4.8**	29.5%	10.7%	1.0%
Total S. & Cent. America	3.5	9.2	9.9	14.6	18.1	19.6	18.9	15.2	13.5	14.5	**13.1**	-9.5%	23.4%	2.7%
Belgium	6.8	6.5	6.3	4.1	3.1	2.9	3.6	2.4	1.3	3.3	**7.2**	117.9%	0.9%	1.5%
France	13.3	14.7	14.4	9.8	8.3	6.9	6.4	9.1	10.9	12.7	**22.9**	79.8%	-0.1%	4.7%
Italy	3.0	9.3	9.1	7.1	5.8	4.5	5.9	5.9	8.2	8.2	**13.5**	64.2%	17.5%	2.8%
Spain	27.5	28.2	23.9	21.4	15.7	16.2	13.7	13.8	16.6	15.0	**21.9**	46.0%	-6.6%	4.5%
Turkey	6.0	7.8	5.9	7.6	5.9	7.1	7.5	7.6	10.9	11.4	**12.9**	12.4%	7.5%	2.7%
United Kingdom	10.1	18.8	24.7	13.9	9.2	11.2	13.7	10.7	6.6	7.2	**18.0**	151.9%	24.3%	3.7%
Other EU	3.7	3.9	4.9	4.4	3.7	3.3	5.2	6.9	10.2	13.4	**23.4**	74.7%	13.6%	4.8%
Rest of Europe	–	†	–	†	–	†	–	†	0.1	†	**†**	26.8%	n/a	◆
Total Europe	70.5	89.1	89.2	68.2	51.8	52.1	56.0	56.4	64.7	71.3	**119.8**	68.1%	2.2%	24.7%
Egypt	–	–	–	–	–	–	3.9	10.7	8.3	3.2	**–**	-100.0%	n/a	–
Kuwait	0.9	2.8	3.0	2.8	2.3	3.6	4.3	4.7	4.8	4.3	**5.1**	19.0%	n/a	1.1%
United Arab Emirates	–	0.2	1.4	1.4	1.6	1.6	2.9	4.2	3.0	1.0	**1.6**	55.0%	n/a	0.3%
Other Middle East & Africa	–	–	–	–	0.5	0.1	2.7	4.8	5.3	4.0	**2.8**	-30.9%	n/a	0.6%
Total Middle East & Africa	0.9	3.0	4.4	4.2	4.3	5.3	13.7	24.5	21.4	12.5	**9.5**	-24.1%	n/a	2.0%
China	8.0	13.0	16.9	20.1	25.1	27.3	27.0	36.8	52.9	73.5	**84.8**	15.4%	31.8%	17.5%
India	13.0	11.5	17.4	18.4	18.0	19.1	20.0	24.3	26.1	30.6	**32.9**	7.4%	10.5%	6.8%
Japan	88.9	96.4	108.6	119.8	120.4	121.8	115.9	113.6	113.9	113.0	**105.5**	-6.6%	1.7%	21.7%
Malaysia	–	–	–	–	2.0	2.2	2.2	1.5	2.0	1.8	**3.3**	85.7%	n/a	0.7%
Pakistan	–	–	–	–	–	–	1.5	4.0	6.1	9.4	**11.8**	25.6%	n/a	2.4%
Singapore	–	–	–	–	1.3	2.6	3.0	3.2	4.1	4.5	**5.0**	10.1%	n/a	1.0%
South Korea	35.3	45.0	47.7	49.7	55.3	51.8	45.8	46.3	51.4	60.2	**55.6**	-7.6%	4.6%	11.5%
Taiwan	12.4	15.0	16.3	17.1	17.2	18.6	19.6	20.4	22.7	22.9	**22.8**	-0.5%	6.2%	4.7%
Thailand	–	–	1.1	1.4	2.0	1.9	3.6	3.9	5.2	6.0	**6.7**	11.5%	n/a	1.4%
Other Asia Pacific	–	–	–	0.1	–	–	–	–	–	0.8	**5.7**	576.6%	n/a	1.2%
Total Asia Pacific	157.5	180.9	207.9	226.6	241.2	245.2	238.5	253.9	284.6	322.7	**334.1**	3.5%	7.1%	68.9%
Total LNG imports	**249.7**	**302.4**	**328.3**	**324.9**	**326.8**	**333.6**	**337.1**	**358.3**	**393.3**	**430.6**	**485.1**	**12.7%**	**6.2%**	**100.0%**

Gross LNG trade
†Less than 0.05.

◆Less than 0.05%.
n/a not available.

Source: includes GIIGNL, IHS.

(Source: BP Statistical Review of World Energy 2020)

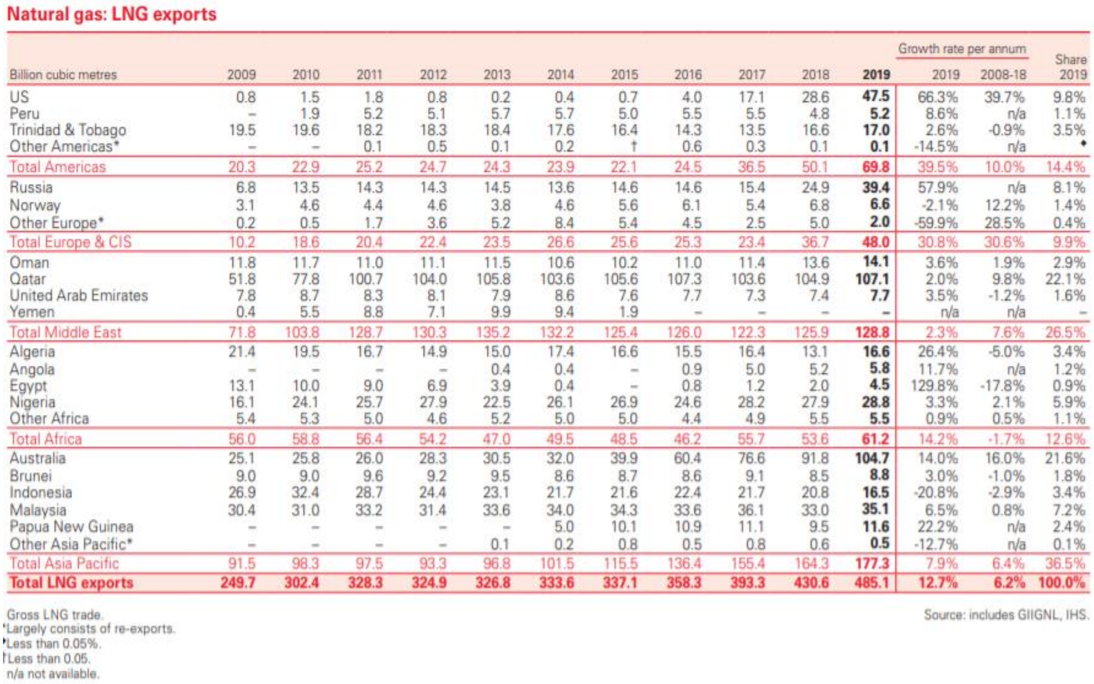
According to Table 1, Asia Pacific remained the largest importing region, taking in just over half of global supply at 68.9%. Following, Europe holds a share of 24.7% of total LNG demand.

Total LNG imports reached 485.1 bcm in 2019 with Japan holding the biggest share with 105.5 bcm. It was followed by China with 84.8 bcm and South Korea with 55.6 bcm . Other major lng importing countries in 2019 as per BP report were:

- India: 32.9 bcm
- France: 22.9 bcm
- Taiwan: 22.8 bcm
- Spain: 21.9 bcm
- United Kingdom: 18.0 bcm
- Italy:13.5 bcm
- Turkey: 12.9 bcm
- Pakistan: 11.8 bcm
- Belgium: 7.2 bcm

3.3 LNG Exports

Table 2: LNG Exports by Nation from 2009 to 2019



Natural gas: LNG exports

												Growth rate per annum		Share
Billion cubic metres	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	**2019**	2019	2008-18	2019
US	0.8	1.5	1.8	0.8	0.2	0.4	0.7	4.0	17.1	28.6	**47.5**	66.3%	39.7%	9.8%
Peru	–	1.9	5.2	5.1	5.7	5.7	5.0	5.5	5.5	4.8	**5.2**	8.6%	n/a	1.1%
Trinidad & Tobago	19.5	19.6	18.2	18.3	18.4	17.6	16.4	14.3	13.5	16.6	**17.0**	2.6%	-0.9%	3.5%
Other Americas*	–	–	0.1	0.5	0.1	0.2	†	0.6	0.3	0.1	**0.1**	-14.5%	n/a	◆
Total Americas	20.3	22.9	25.2	24.7	24.3	23.9	22.1	24.5	36.5	50.1	**69.8**	39.5%	10.0%	14.4%
Russia	6.8	13.5	14.3	14.3	14.5	13.6	14.6	14.6	15.4	24.9	**39.4**	57.9%	n/a	8.1%
Norway	3.1	4.6	4.4	4.6	3.8	4.6	5.6	6.1	5.4	6.8	**6.6**	-2.1%	12.2%	1.4%
Other Europe*	0.2	0.5	1.7	3.6	5.2	8.4	5.4	4.5	2.5	5.0	**2.0**	-59.9%	28.5%	0.4%
Total Europe & CIS	10.2	18.6	20.4	22.4	23.5	26.6	25.6	25.3	23.4	36.7	**48.0**	30.8%	30.6%	9.9%
Oman	11.8	11.7	11.0	11.1	11.5	10.6	10.2	11.0	11.4	13.6	**14.1**	3.6%	1.9%	2.9%
Qatar	51.8	77.8	100.7	104.0	105.8	103.6	105.6	107.3	103.6	104.9	**107.1**	2.0%	9.8%	22.1%
United Arab Emirates	7.8	8.7	8.3	8.1	7.9	8.6	7.6	7.7	7.3	7.4	**7.7**	3.5%	-1.2%	1.6%
Yemen	0.4	5.5	8.8	7.1	9.9	9.4	1.9	–	–	–	**–**	n/a	n/a	–
Total Middle East	71.8	103.8	128.7	130.3	135.2	132.2	125.4	126.0	122.3	125.9	**128.8**	2.3%	7.6%	26.5%
Algeria	21.4	19.5	16.7	14.9	15.0	17.4	16.6	15.5	16.4	13.1	**16.6**	26.4%	-5.0%	3.4%
Angola	–	–	–	–	0.4	0.4	–	0.9	5.0	5.2	**5.8**	11.7%	n/a	1.2%
Egypt	13.1	10.0	9.0	6.9	3.9	0.4	–	0.8	1.2	2.0	**4.5**	129.8%	-17.8%	0.9%
Nigeria	16.1	24.1	25.7	27.9	22.5	26.1	26.9	24.6	28.2	27.9	**28.8**	3.3%	2.1%	5.9%
Other Africa	5.4	5.3	5.0	4.6	5.2	5.0	5.0	4.4	4.9	5.5	**5.5**	0.9%	0.5%	1.1%
Total Africa	56.0	58.8	56.4	54.2	47.0	49.5	48.5	46.2	55.7	53.6	**61.2**	14.2%	-1.7%	12.6%
Australia	25.1	25.8	26.0	28.3	30.5	32.0	39.9	60.4	76.6	91.8	**104.7**	14.0%	16.0%	21.6%
Brunei	9.0	9.0	9.6	9.2	9.5	8.6	8.7	8.6	9.1	8.5	**8.8**	3.0%	-1.0%	1.8%
Indonesia	26.9	32.4	28.7	24.4	23.1	21.7	21.6	22.4	21.7	20.8	**16.5**	-20.8%	-2.9%	3.4%
Malaysia	30.4	31.0	33.2	31.4	33.6	34.0	34.3	33.6	36.1	33.0	**35.1**	6.5%	0.8%	7.2%
Papua New Guinea	–	–	–	–	–	5.0	10.1	10.9	11.1	9.5	**11.6**	22.2%	n/a	2.4%
Other Asia Pacific*	–	–	–	–	0.1	0.2	0.8	0.5	0.8	0.6	**0.5**	-12.7%	n/a	0.1%
Total Asia Pacific	91.5	98.3	97.5	93.3	96.8	101.5	115.5	136.4	155.4	164.3	**177.3**	7.9%	6.4%	36.5%
Total LNG exports	**249.7**	**302.4**	**328.3**	**324.9**	**326.8**	**333.6**	**337.1**	**358.3**	**393.3**	**430.6**	**485.1**	**12.7%**	**6.2%**	**100.0%**

Gross LNG trade.
*Largely consists of re-exports.
◆Less than 0.05%.
†Less than 0.05.
n/a not available.

Source: includes GIIGNL, IHS.

(Source: BP Statistical Review of World Energy 2020)

As we can see from Table 2, the first country of the world in LNG exports is Qatar. According to the BP Statistical Review, Qatar's export of LNG was already at 107.1 billion cubic meters (bcm) through 2020. The Doha-headquartered Qatar gas is the world’s most significant LNG producing company.

Australia is ranked second on the list, with 104.7 billion cubic meters of LNG exported last year. In Australia, one of the world's largest LNG projects, the Ichthys LNG, is under construction, including that of the development of the Ichthys gas-condensate field, which is located roughly 220 kilometers offshore of the west side of country.

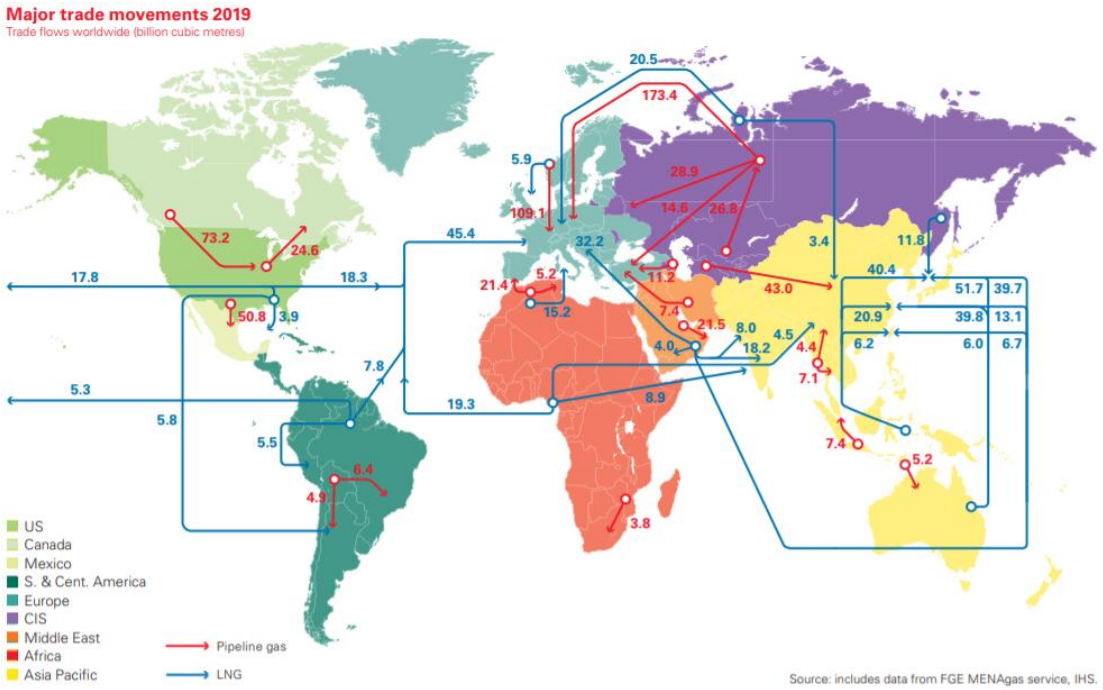
In the third position of top LNG exporting markets, we meet the United States with an exporting capacity of 47.5 bcm. In 2018, the North American country supplied 6.7 percent of the global LNG exports. Until May of 2019, the United Nations has more than 110 LNG facilities in operation, providing a variety of services, some of which transported the product to overseas markets.

According to the BP survey, other major exporters and their export quantities for 2019 were:

- Russia: 39.4 bcm
- Malaysia: 35.1 bcm
- Nigeria: 28.8 bcm
- Trinidad & Tobago: 17 bcm
- Algeria: 16.6 bcm
- Indonesia: 16.5 bcm
- Oman: 14.1 bcm
- Papua New Guinea: 11.6 bcm

3.4 LNG International Trade

Figure 1: Major Trade Flows Worldwide 2019



(Source: BP Statistical Review of World Energy 2020 | 69th edition)

The above figure (Figure 1) gives a clear view of global major trade flows. The high demand in Republic of China and in Southeast Asia and the increasing supply from Australia create the largest global LNG trade flow route and this is the intra-Pacific trade flow. Trade between the Pacific and Middle East was the second-highest by volume trade, because of the crucial role of Qatar in supplying of Japan, South Korea, and China.

The South China Sea is a significant route for trade of liquefied natural gas, and in 2016, almost 40% of global LNG trade, or about 4.7 trillion cubic feet (Tcf), passed through this sea. Qatar and Malaysia be using the South China Sea as a key trading route. The two LNG exporters around each other accounted for more than half of all LNG volumes in the South China Sea. In 2016, the South China Sea saw over half of Qatar's worldwide LNG shipments. Considering Malaysia's only LNG export complex is located on the South China Sea coast, all of the country's LNG exports flow through this one. Many other LNG major producers use the South China Sea to reach LNG customers. Brunei, Oman, and the UAE exported between 84 percentage and 100 percent of their total LNG shipments throughout the South China Sea in 2016. Alternative exporting nations of the region, such as Indonesia and Australia, are often traveling on other trade routes to LNG markets. Roughly 23% of Australian LNG exports and 29% of Indonesian LNG exports were transported all across South China Sea in 2016. Much of Australia and Indonesia's remaining LNG exportation went east of the Philippines and Taiwan to prevent the South China Sea from accessing the South Korean, North China and Japanese markets. (U.S. EIA, 2017)

What is more, according to International Gas Union “Intra-Atlantic trade remained the third largest route by volume, although Atlantic-Pacific trade grew by 11.6 MT during 2018, becoming the fourth largest route”. (IGU, 2020) It is clear that Pacific Ocean attracted more LNG from the Atlantic Basin, largely the result of higher LNG flows from the United Nations to Asian markets through the Panama Canal. Flows into the Middle East remain relatively small, with other Middle East and Atlantic Basin sources providing nearly all of those markets’ imports.

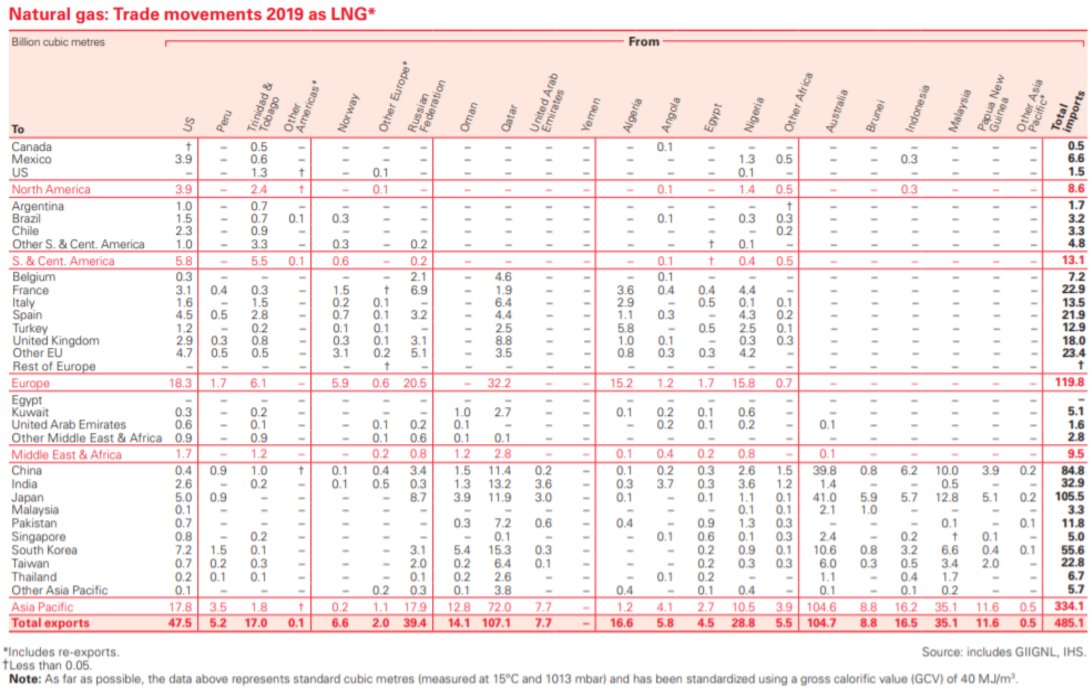
In terms of Africa, exports were mostly to Asia and Europe (13.6 MT and 25.1 MT, respectively), with additional exports from Algeria and Egypt, as well as worldwide demand increases in China. A total of 2.9 MT of African supplies were imported into Asia Pacific, a decrease from the previous year, while 1.5 MT was imported into North America, a rise from the previous year, with virtually all of it going to Mexico. The worldwide distribution of North American supply was comparable to that seen in 2018, with quantities being imported into Europe, Asia, Asia Pacific, North and Latin America, and the Middle East.

The largest flow was, predictably given 2019’s price developments, into Europe (12.7 MT). What is more, significant flows went to Asia Pacific (9.5 MT). FSU (Russia) exports topped at 29.3 MT, of which more than half was destined for european continent in 2019. At this point Agency for the Cooperation of Energy Regulators (ACER) claims that the future role of natural gas in the EU is intensely debated. In order to become a carbon-neutral economy by 2050, the use of unabated natural gas would need to drastically decrease.

According to the survey of International Gas Union in 2020 “A significant volume also went to Asia Pacific (8.8 MT), mainly Japan (6.3 MT), as the Northern Sea route trade flow grew steadily. Latin American volumes showed a similar global distribution in 2018 and 2019 as North American volumes. Intra-Latin American trade decreased, and instead more volumes went to Europe (5.9 MT) and Asia (1.9 MT). Imports into North America remained similar to last year (3.1 MT). Lastly, European volumes remained within Europe (4.2 MT), meaning Norway’s lowered exports were mainly imported into other European markets, with almost half destined for France (1 MT) and Lithuania (1 MT)” (IGU, 2020)

The following table (table 3) shows in detail the LNG trade movements of 2019 among every country and continent. The vertical axis of the graph shows the LNG imports and the horizontal axis gives a picture of LNG amounts that every country exports.

Table 3: Global LNG Trade Movements of 2019



Natural gas: Trade movements 2019 as LNG*

Billion cubic metres	From																					
To	US	Peru	Trinidad & Tobago	Other Americas*	Norway	Other Europe*	Russian Federation	Oman	Qatar	United Arab Emirates	Yemen	Algeria	Angola	Egypt	Nigeria	Other Africa	Australia	Brunei	Indonesia	Malaysia	Papua New Guinea	Other Asia Pacific*	**Total imports**
Canada	†	–	0.5	–	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	–	–	**0.5**
Mexico	3.9	–	0.6	–	–	–	–	–	–	–	–	–	–	–	1.3	0.5	–	–	0.3	–	–	–	**6.6**
US	–	–	1.3	†	–	0.1	–	–	–	–	–	–	–	–	0.1	–	–	–	–	–	–	–	**1.5**
North America	3.9	–	2.4	†	–	0.1	–	–	–	–	–	–	0.1	–	1.4	0.5	–	–	0.3	–	–	–	**8.6**
Argentina	1.0	–	0.7	–	–	–	–	–	–	–	–	–	–	–	–	†	–	–	–	–	–	–	**1.7**
Brazil	1.5	–	0.7	0.1	0.3	–	–	–	–	–	–	–	0.1	–	0.3	0.3	–	–	–	–	–	–	**3.2**
Chile	2.3	–	0.9	–	–	–	–	–	–	–	–	–	–	–	–	0.2	–	–	–	–	–	–	**3.3**
Other S. & Cent. America	1.0	–	3.3	–	0.3	–	0.2	–	–	–	–	–	–	†	0.1	–	–	–	–	–	–	–	**4.8**
S. & Cent. America	5.8	–	5.5	0.1	0.6	–	0.2	–	–	–	–	–	0.1	†	0.4	0.5	–	–	–	–	–	–	**13.1**
Belgium	0.3	–	–	–	–	–	2.1	–	4.6	–	–	–	0.1	–	–	–	–	–	–	–	–	–	**7.2**
France	3.1	0.4	0.3	–	1.5	†	6.9	–	1.9	–	–	3.6	0.4	0.4	4.4	–	–	–	–	–	–	–	**22.9**
Italy	1.6	–	1.5	–	0.2	0.1	–	–	6.4	–	–	2.9	–	0.5	0.1	0.1	–	–	–	–	–	–	**13.5**
Spain	4.5	0.5	2.8	–	0.7	0.1	3.2	–	4.4	–	–	1.1	0.3	–	4.3	0.2	–	–	–	–	–	–	**21.9**
Turkey	1.2	–	0.2	–	0.1	0.1	–	–	2.5	–	–	5.8	–	0.5	2.5	0.1	–	–	–	–	–	–	**12.9**
United Kingdom	2.9	0.3	0.8	–	0.3	0.1	3.1	–	8.8	–	–	1.0	0.1	–	0.3	0.3	–	–	–	–	–	–	**18.0**
Other EU	4.7	0.5	0.5	–	3.1	0.2	5.1	–	3.5	–	–	0.8	0.3	0.3	4.2	–	–	–	–	–	–	–	**23.4**
Rest of Europe	–	–	–	–	–	†	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**†**
Europe	18.3	1.7	6.1	–	5.9	0.6	20.5	–	32.2	–	–	15.2	1.2	1.7	15.8	0.7	–	–	–	–	–	–	**119.8**
Egypt	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	**–**
Kuwait	0.3	–	0.2	–	–	–	–	1.0	2.7	–	–	0.1	0.2	0.1	0.6	–	–	–	–	–	–	–	**5.1**
United Arab Emirates	0.6	–	0.1	–	–	0.1	0.2	0.1	–	–	–	–	0.2	0.1	0.2	–	0.1	–	–	–	–	–	**1.6**
Other Middle East & Africa	0.9	–	0.9	–	–	0.1	0.6	0.1	0.1	–	–	–	–	–	–	–	–	–	–	–	–	–	**2.8**
Middle East & Africa	1.7	–	1.2	–	–	0.2	0.8	1.2	2.8	–	–	0.1	0.4	0.2	0.8	–	0.1	–	–	–	–	–	**9.5**
China	0.4	0.9	1.0	†	0.1	0.4	3.4	1.5	11.4	0.2	–	0.1	0.2	0.3	2.6	1.5	39.8	0.8	6.2	10.0	3.9	0.2	**84.8**
India	2.6	–	0.2	–	0.1	0.5	0.3	1.3	13.2	3.6	–	0.3	3.7	0.3	3.6	1.2	1.4	–	–	0.5	–	–	**32.9**
Japan	5.0	0.9	–	–	–	–	8.7	3.9	11.9	3.0	–	0.1	–	0.1	1.1	0.1	41.0	5.9	5.7	12.8	5.1	0.2	**105.5**
Malaysia	0.1	–	–	–	–	–	–	–	–	–	–	–	–	–	0.1	0.1	2.1	1.0	–	–	–	–	**3.3**
Pakistan	0.7	–	–	–	–	–	–	0.3	7.2	0.6	–	0.4	–	0.9	1.3	0.3	–	–	–	0.1	–	0.1	**11.8**
Singapore	0.8	–	0.2	–	–	–	–	–	0.1	–	–	–	0.1	0.6	0.1	0.3	2.4	–	0.2	†	0.1	–	**5.0**
South Korea	7.2	1.5	0.1	–	–	–	3.1	5.4	15.3	0.3	–	–	–	0.2	0.9	0.1	10.6	0.8	3.2	6.6	0.4	0.1	**55.6**
Taiwan	0.7	0.2	0.3	–	–	–	2.0	0.2	6.4	0.1	–	–	–	0.2	0.3	0.3	6.0	0.3	0.5	3.4	2.0	–	**22.8**
Thailand	0.2	0.1	0.1	–	–	–	0.1	0.2	2.6	–	–	–	0.1	0.2	–	–	1.1	–	0.4	1.7	–	–	**6.7**
Other Asia Pacific	0.1	–	–	–	–	0.2	0.3	0.1	3.8	–	–	0.4	–	0.1	0.4	–	0.1	–	0.1	0.2	–	–	**5.7**
Asia Pacific	17.8	3.5	1.8	†	0.2	1.1	17.9	12.8	72.0	7.7	–	1.2	4.1	2.7	10.5	3.9	104.6	8.8	16.2	35.1	11.6	0.5	**334.1**
Total exports	**47.5**	**5.2**	**17.0**	**0.1**	**6.6**	**2.0**	**39.4**	**14.1**	**107.1**	**7.7**	**–**	**16.6**	**5.8**	**4.5**	**28.8**	**5.5**	**104.7**	**8.8**	**16.5**	**35.1**	**11.6**	**0.5**	**485.1**

*Includes re-exports.
†Less than 0.05.
Note: As far as possible, the data above represents standard cubic metres (measured at 15°C and 1013 mbar) and has been standardized using a gross calorific value (GCV) of 40 MJ/m³.

Source: includes GIIGNL, IHS.

(Source: BP Statistical Review of World Energy 2020)

3.5 Conclusions

Due to the erratic nature of the regional LNG market, the strong competition and the rapidly emergence of new technologies, it is not easy to predict the future of LNG trades. What is more, it is true that global demand of gas is highly linked to global economic growth and the economic decline could slow the demand and as a result to harm the expansion of supply chains.

However, due to the reason that LNG has the ability to offer a global commodity that can fulfill the growth of demand for natural gas forecast in many markets all over the world many are sure that the LNG industry will continue to grow at a strong average yearly level.

Security of energy supplies, higher natural gas prices, lower LNG production costs, increased demand for gas imports coupled with growing demand for clean energy in both developed and emerging nations, and the desire of gas producers to monetize their reserves all combine to set the stage for an increase in LNG trade in the near future.

To sum up, over the past few decades more and more large companies of the energy sector have turned their interest in development of longstanding LNG supply chains. They have started also to invest significant funds in order to develop new projects for shipping transportation of LNG among exporting and importing nations.

Chapter 4: LNG Terminals

4.1 Introduction

This chapter is going to examine the LNG terminals all over the world. Firstly, some important aspects of LNG importing terminals and their four basics functions are discussed. The first one is the berthing of LNG tankers and unloading or reloading of cargoes, storage and regasification are follow and finally, is analyzed the send-out of this gas into the transmission grid. LNG is delivered to receiving terminals, which then returns LNG to a gaseous state. Thereafter the natural gas is transmitted by pipelines to every natural gas customer. There are two types of LNG terminals: the onshore and the offshore/ floating terminal. Each of them has benefits and drawbacks. In this chapter will be analyzed both offshore and onshore terminals, with emphasis in the second one as it is the most common in energy area. Also, follows a study about LNG receiving capacity by status and region. Last but not least, the chapter concludes with the LNG import terminals in Greece.

4.2 Functions of a Receiving Terminal

An LNG terminal is a facility that receives and regasifies liquefied natural gas (LNG) from manufacturing zones by LNG tanker.

A standard terminal serves four purposes:

i. Berthing of LNG tankers and unloading or reloading of cargoes:

Once they arrive at terminals, the LNG containers are anchored at the discharge berth. The articulated arms are then connected to the LNG carrier for the discharge of LNG and transfer into the terminal storage tanks. The LNG runs via pipes constructed specifically for at least 12 hours to resist very low temperatures (-160°C). In order to maintain the pressure in the freighter tanks, certain amount of boil off gas is returned from the terminal storage to the LNG tanker.

ii. Storage of LNG in cryogenic tanks (-160°C):

The second stage is to storage the LNG, is is stored in cryogenic tanks capable of withstanding temperatures of -160°C in order to maintain the gas in liquid form. For the purpose of limiting the evaporation, the outer walls of tanks are constructed with pre-stressed reinforced concrete. Despite the above techniques, a small amount of heat still penetrates the LNG tanks, as a result it causes a slight evaporation of LNG. Using compressor and recondensing technologies, the resultant boil-off gas is collected and supplied back into the LNG flow.

Boil off gas can no longer be collected during maintenance times and is burned off through the torches. Instead, methane should be consumed since the influence on greenhouse effect can therefore be minimized rather than released into the environment.

iii. Regasification of LNG:

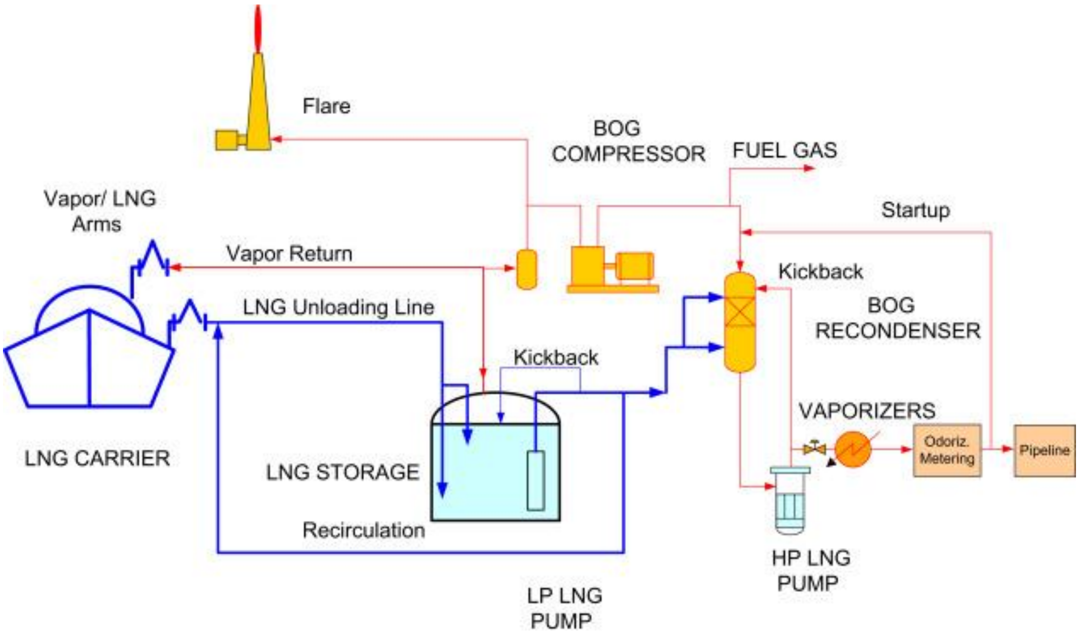
At Regasification stage, LNG is pressurized and degasified with the method of heat exchangers. LNG is pressurized under an atmospheric pressure (at around 80 times), until it turns back into a gaseous form.

iv. Send-out of this gas into the transmission grid:

The natural gas undergoing numerous treatments when LNG is restored to its gaseous form. The odourless natural gas is artificially odorised with a little amount of tetrahydrothiophee (THT), which provides gas with its own unique odor familiar to everyone before being delivered through into the National Transmission Grid (GRTgaz). This is a very important measure of safety since it can identify any gas leak by its scent. (Mokhatab, 2014)

The figure 2 "Functions of a Receiving Terminal" is an illustration of all above functions that this section presents.

Figure 2: Functions of a Receiving Terminal

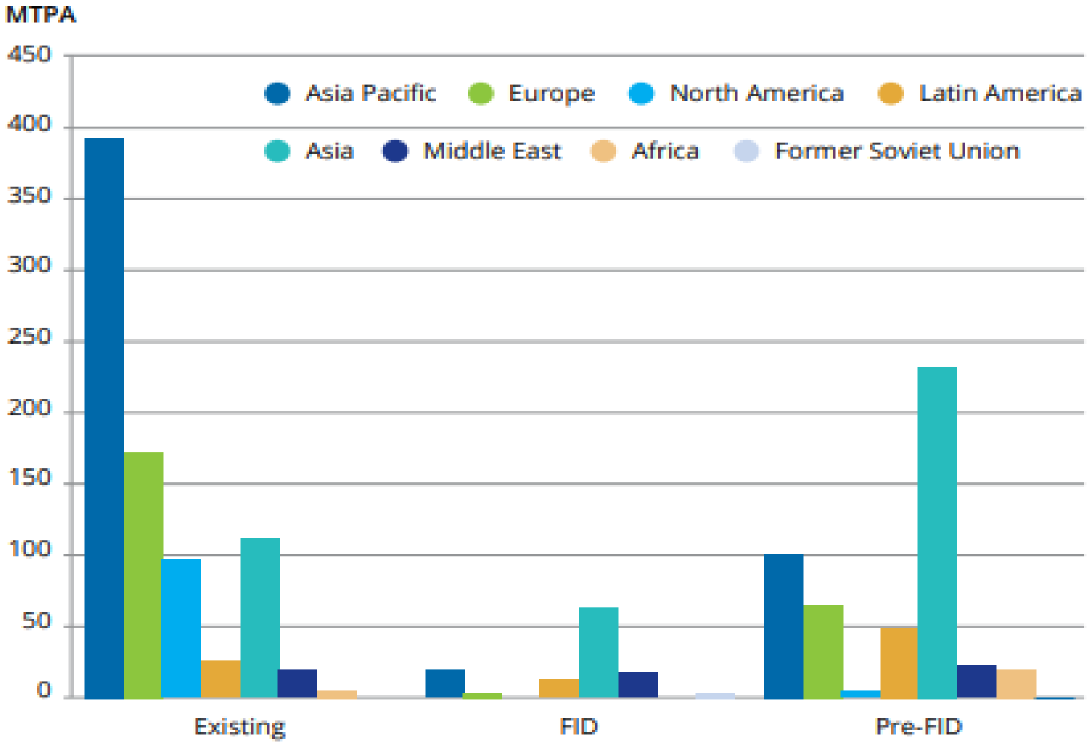


(Source: Handbook of Liquefied Natural Gas, 2013)

4.3 LNG Terminals by Market.

On a worldwide scale, LNG regasification capacity has reached 821 MTPA, and this trend is likely to continue as the liquefaction process is expanded to satisfy rising demand. The installation of several new terminals and three major expansions at existing terminals between 2019 and 2020 reportedly increased LNG regasification capacity in the international economy to 821 MTPA across 37 markets by February 2020. China, India, Bangladesh, Brazil, and Jamaica installed seven new LNG terminals in the current markets. Also two markets that successfully expanded their existing LNG receiving plants are India and Thailand. They contribute in this way in the global regasification capacityDuring 2019, a total of 23.4 MTPA of receiving capacity was added, with India adding the most, 5.0 MTPA, from a new onshore station. Projects for floating regasification have also been added. The overall amount of markets does not include those with small-scale regasification capacity of less than 0.5 MTPA, such as Sweden, Finland, Norway and Malta. On the other side, it covers markets with significant regeneration capacity that exclusively consume cargos produced locally (e.g. Indonesia). Asian markets have been the most regenerating capacities in the aggregate and are expected to maintain good growth through development of capacities on both new and existing markets. Regasification capacity expansion was constrained in North America while domestic gas production surged in recent years. A number of additional North American import terminals, including Freeport, Elba Island, and Cameron, have been converted to liquefaction production operations, in addition to Cove Point and Sabine Pass, which have been functioning ostensibly as bi-directional importing and exporting facilities. As witnessed in Asia and Latin America, FSRUs have gained a prominent role in providing regasification capacity to new markets. Bangladesh successfully boosted its capacity by launching another FSRU project in 2019 after adding its first floating regasification terminalObviously, given the availability of the pipeline and offloading capabilities, FSRUs provide a rapid solution to access new markets in the global LNG trade. On the other hand, established importers of LNG, such as South Koreans and China, are expanding their regasification capacity by building a solid long-term solution that enables future storage to grow onshore regasification stations.

Figure 3: LNG Receiving Capacity by Status and Region, as of February 2019



(Source: IGU, 2020)

According to the above figure 3 “LNG Receiving Capacity by Status and Region, as of February 2019” it is clear that:

1) Japan has the world's greatest regasification capacity and is also the world's largest LNG importer. In the year 2019, Japan's regasification capacity was 210.5 MTPA. Despite not creating any new regasification capacity in 2019, Japan is projected to keep growing its importing capabilities through new terminals and development projects in 2019. The construction of a new 0.5 MTPA receiving port in the Niihama area of western Japan has commenced, with completion scheduled for February 2022. By the end of the year, Japan's regasification utilization had risen to 36%.

2) The second largest regasification capacity market globally in 2019 is South Korea.

In 2019, South Korea provided 125.8 MTPA of regasification capacity to the worldwide LNG market, thanks to six existing import terminals.

3) In terms of total regasification capacity, Republic of China is the third largest market in the world with 77.4 MTPA of nameplate capacity by the end of 2019. With six new onshore projects under construction and four existing terminals undergoing expansion, China is set to add up to 28.9 MTPA of regasification capacity by 2023. China's strong regasification growth rate is expected to continue, closing the gap with South Korea and Japan. China's regasification utilisation rate was 74% in 2019, a steady increase since 2016.

4) As far as Europe, European markets account for approximately 20% of total global regasification capacity. However, regasification capacity additions have been relatively slow in Europe. Never the less, some European markets have regasification projects currently under construction such as Kroatia. Until 2021, the Krk project, a 1.9 MTPA FSRU-based terminal which began construction in April 2019, will allow Croatia to access the global LNG market as a new importer. Moreover, some of the highest utilisation rates were observed in terminals located in Belgium, Portugal and Italy. Over the past year, European markets absorbed most of the new LNG supplies from US and Russia, largely due to insufficient growth in Asian LNG demand through the summer months and low prices in Asia. Europe's liquid market and slightly high. Europe's liquid market and slightly higher netback attracted new LNG supplies to the region. The over-supply situation at European terminals also drove very high levels of storage tank utilisation rates during the past year. At the six terminals of the Spanish gas system, storage capacity had an average utilisation rate of 77% and peak rate at 99% during 2019.

5) Despite having the world's third-highest regasification capacity, the United States has poor terminal utilization rates. In 2019, utilization rates averaged 5%, largely due to liquefied natural gas imports to Puerto Rico. In recent years, the Penuelas regasification terminal has seen significant amounts of LNG imports, achieving a terminal utilization rate of 120 percent in 2019. Puerto Rico intends to increase regasification capacity with the construction of

a second FSRU-based facility in San Juan in 2020. Only a few other US terminals received low volume LNG cargoes from 2018 to 2019, with the exception of Puerto Rico's terminal and Exelon's Everett Massachusetts LNG facility. These cargoes are likely to be used as tank cooling supplies related to the addition of liquefaction capacity to existing regasification terminals, which will normally function as bidirectional facilities. The six operational regasification terminals in the United States have a total import capacity of 45.4 MTPA as of February 2020. Because of the US's large-scale domestic shale output and limited gas supplies, the US is expected to cut LNG imports even more and prioritize LNG export projects over import terminals.

6) Latin America, with 32.1 MTPA of regasification capacity, is anticipated to add another 6.6 MTPA by the end of 2021, thanks to the building of new FSRU-based terminals in current Brazil and new markets like El Salvador. Sergipe terminal in Brazil shows the unloading with its first commissioning cargo at its Golar Nanook FSRU in April 2019, and its second commercial cargo in the start of 2020. Once the deployed FSRU arrives and is commissioned at its allocated ports, the Port of Acu, a forthcoming facility in Brazil, is projected to import LNG cargoes till 2021. The Acajutla LNG project in El Salvador, that started building in January 2019, consists of an offshore FSRU, an underground pipeline project, and three sub - stations, and is scheduled to be completed in the middle of 2021.

4.4 LNG Import Terminals in Greece

In this section the natural gas in the Greek market will be studied. Regarding the relationship between supply and demand, in Greece only a small amount of natural gas is produced in relation to the requested quantity. The demand for natural gas in the country is growing at a steady and rapid pace. Gas consumption in the Greek market increased by 68 percent between 2014 and 2017, with a 21 percent rise in 2017 compared to 2016. Natural gas contributes for roughly 14 percent of Greece's total main energy supply, with LNG accounting for approximately 25 percent, which is imported into Greece's sole LNG station at Revithoussa. The remainder is imported through pipeline from Russia. The Revithoussa LNG Terminal is located on the islet of Revithoussa, in the gulf of Pachi at Megara, 45 km west of Athens.

The LNG terminal in Revithoussa came into operation in 2000 and be placed among the first twenty eight LNG terminals which operate today in the region of Mediterranean and in Europe. What is more, Revithoussa's terminal is the only one in Greece that receives LNG cargoes, temporarily stores and regasifies LNG and supplies the National Natural Gas Transmission System of Greece.

Revithoussa's terminal is a very significant asset of country as it holds a storage capacity of 225,000 m3 LNG and a regasification capacity of 1250 m3/h as a Sustained Maximum Send out Rate,

For the above reason, the Terminal provides an operational flexibility in the transmission system, security of energy supply and increased capability to meet the peak of nation's gas demand.

PLANNED LNG TERMINAL IN GREECE: The Alexandroupolis Independent Natural Gas System (INGS) intends to build a floating LNG terminal in the Aegean Sea, approximately 17.6 kilometers south-west of Alexandroupolis, Greece. The Alexandroupolis INGS will have a floating storage and regasification unit (FSRU) capable of transporting, storing, and converting LNG to natural gas. A subsea and onshore gas transmission system will also be installed. The FSRU will also have a storage capacity of up to 170,000 cm of LNG and a regasification capability of 5.5 billion cubic meters per year.

4.5 Conclusions

The development and completion of a huge number of LNG terminals and gas management infrastructures have taken place in recent years, particularly in Asia. As a result of this development, LNG became established in the global energy trade. On a worldwide scale, it is obvious that Asian markets have contributed the highest amount of regasification capacity, and it is expected that their positive growth will continue as a result of capacity increases in gas markets. Japan is the world's largest LNG importer and also has the world's largest LNG regasification capacity, followed by Korea and China. Japan is the world's largest LNG importer and also has the world's largest LNG regasification capacity. Furthermore, the European markets account for around 20% of total worldwide regasification capacity, according to industry estimates. As a result of the development of LNG terminals and infrastructure, LNG plays an important part in the global energy trade. In order to overcome every hurdle to LNG transit from one continent to another, the construction of more and more LNG projects on a worldwide scale is a significant problem.

Chapter 5: LNG Pricing

5.1 Introduction

Chapter 5 discusses the Pricing of LNG and gas generally. Price levels are determined by both internal and external factors. Regarding the internal factors, the price formations and the structure of each gas market play an important role, as well as the balances of supply and demand for the product. On the other hand, LNG trade can facilitate arbitrage between markets. The above reasons have led to significant price disparities among gas markets around the world. Last but not least, the use of different gas pricing systems from market to market enhances the price gap.

Either in case of gas which be delivered via pipelines or in case of LNG , there are the some common pricing regimes. The most significant regimes for pricing natural gas are the follow: First and foremost is the Hub pricing also known as gas-on-gas competition ("GOG") or market-based pricing, in this case natural gas is totally priced based on the interplay between the demand and supply of gas. The next pricing regime called "OPE", which means contractually pricing natural gas using oil or other refined fuels prices. Last, the third way is driven by governments and has close relation with regulated prices which set by them.

5.2 Price Formation Mechanisms

There is no single technique for pricing LNG, and different approaches are utilized in different markets. The price of natural gas is determined by a number of processes. Because gas deposits and production are unevenly distributed on Earth, geopolitics plays a large influence in gas markets, and this, along with technological factors, has always made gas pricing a highly complex matter. (Yegorov & Wirl, 2011). In different domestic and regional gas markets, several price systems have co-existed over the decades. From the importer's side, it is possible to supply natural gas three primary ways: from imports through pipelines, from imports of LNG, and naturally from domestic production. As a result, we distinguish domestic oil pricing from export prices, which would prevent importing countries from having much power over gas prices. The nations which have gas reserves both for internal and export usage utilize follow three primary price creation systems (IGU, 2012).

- Oil Price Escalation (OPE)

Under OPE mechanism, natural gas price is highly linked with competing fuels, such as crude oil, gas oil and/or fuel oil, through a base price and an escalation clause. (Villar & Joutz, 2006)

- Gas-on-Gas Competition (GOG)

The GOS method decides gas prices by utilizing market forces, namely the relationship between demand and supply. Trading occurs at physical hubs like Henry Hub or notional hubs like as NPB, and therefore a short term fixed price basis is determined. In terms of long-term contracts, they utilize gas price indices, for example, to calculate the price per month, rather than competing fuel indices, which are also regarded to be utilizing the Gas-on-Gas Competition mechanism. Spot LNG is also included in this category.

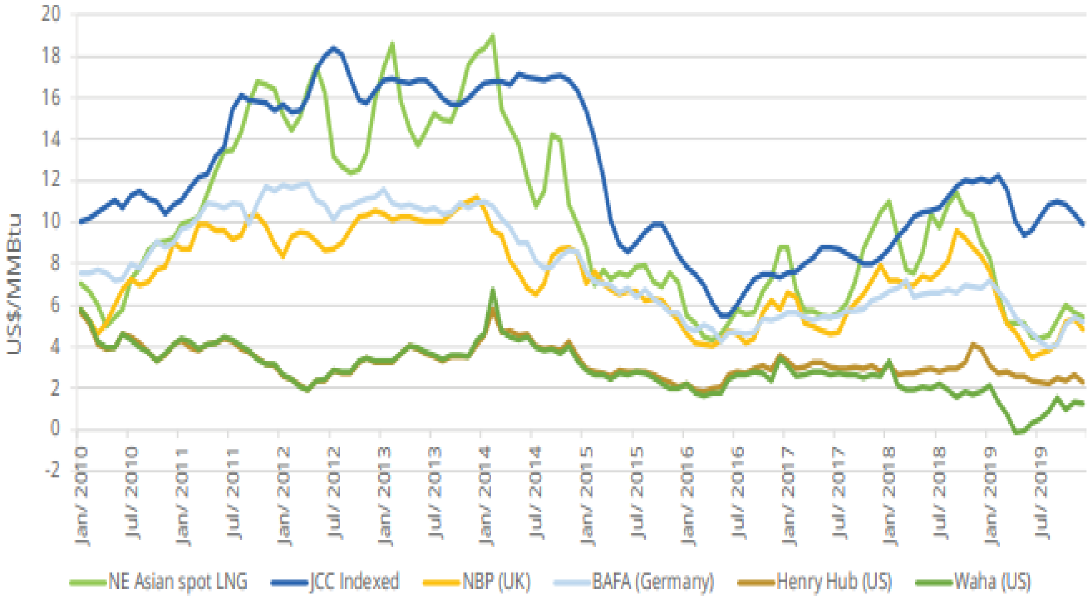
- Bilateral Monopoly (BIM)

According to BIM mechanism, the gas price is being fixed for a specific period of time by bilateral agreements between large entities, usually at the Government / state-owned company level.

5.3 Gas pricing in different markets

There is no universal LNG pricing method and different approaches are utilized in different areas. The most commonly LNG pricing structures are: the oil-linked structure (the price is based on a percentage of oil prices plus the cost of liquefaction and transportation) and the natural gas hub-linked structure (the price is based on percentage of natural gas hub price plus the cost of liquefaction and transportation). Despite the fact that there is no fixed relationship between these structures, the price of gas strongly correlates with oil prices. In addition, different pricing methods are used at different stages of the LNG supply chain. For some customers the base price is determined at the source and for other customers a CIF price is applied. An additional significant point is the fact that pricing is based on the thermal capacity of the LNG, not weight or volume. Thermal capacity of the LNG differs from one source to another in relation to methane content of the LNG

Figure 4: Monthly Average Regional Gas Prices 2010-2020



(Source: Rystad Energy, Bloomberg, Refinitiv, 2020)

As we can see from the figure above (Figure 4), International gas prices fell to record lows in 2019, owing to increased natural gas supply, the completion of new export infrastructure, and Asia's weak demand response. The above figure, presents the average regional gas prices per month from 2010 to 2020, of the 6 characteristic examples of 1) NE Asian spot LNG, 2) JCC Indexed, 3)NBP (UK), 4) Henry Hub (US) and 5) Waha (US). In the United States, Henry Hub front month prices averaged US$2.53 per MMBtu in 2019, down from US$3.07 per MMBtu in 2018, owing to significant shale supply increases. Total natural gas supply in United States meet a growth from 850 Bcm in 2018 to 935 Bcm in 2019. Lower costs and greater well performance were aided by longer laterals and increased proppant intensity. In addition, related gas from oil fields has swamped the US market. (IGU, 2020)

Waha gas prices averaged US$0.9 per MMBtu in 2019, down from US$2.01 per MMBtu in 2018. This was due to increased production and local oversupply in the

Permian area. Waha prices rebounded after the summer of 2019 as new infrastructure helped to debottleneck the Permian Basin. The Gulf Coast Express pipeline commenced operations in the middle of 2019 and is capable of transporting around 20 Bcm of gas eastward to the Agua Dulce receiving point on the Texas Gulf Coast, according to the US Energy Information Administration. Up to the end of 2019, Waha prices averaged US$1.21 per MMBtu since the pipeline's commissioning. The demand of LNG in the United States assimilates the additional supplies coming into the market but it was not able to keep the level of prices.

According to International Gas Union, “In Asia, spot LNG prices averaged US$5.49 per MMBtu in 2019, the lowest level in the last ten years. After reaching a peak of US$11.6 per MMBtu at the end of September 2018 driven by Asian buyers restocking ahead of the winter, prices had a prolonged slide throughout 2019, reaching a low of US$4.1 per MMBtu in August. The decline in prices was caused by a mild winter in both Asia and Europe and a continuous increase in LNG supplies mainly from the US but also from Russia, Australia and others” (IGU, 2020).

Due to the fact that LNG demand in Asian markets was stable, more and more volumes headed to European markets because of the region’s liquid markets and the slightly higher netback. As pipeline shipments from Russia and Norway remained stable, this resulted in a severely skewed European balance. As a result, LNG prices in Europe fell to an all-time low in the summer of 2019, with the NBP front month contract trading as low as US$3.15 per MMBtu, the lowest level in 10 years. In 2019, the NBP front-month contract averaged $4.85 per MMBtu. At the end of the year, prices in Northwest Europe increased by more than 25% to above US$5 per MMBtu, owing to regular winter seasonality and some concern about Russian shipments via Ukraine. Winter prices remained at their lowest level in eight years, notwithstanding the reduction. In terms of German Border Price (BAFA), the average price per MMBtu in 2019 was US$5.26. In comparison to NBP, BAFA traded at an average premium of US$0.4 in 2019, compared to an average discount of US$1.14 in 2018. Unlike the NBP, the price formation at BAFA is still heavily influenced by the oil price due to the large volume of Russian imports exchanged under long-term contracts linked to Brent. (IGU, 2020).

According to European Commission, “The drop of prices in Asia and Europe has resulted in wider spreads between spot prices and oil indexed contracts. Spot prices in Asian markets tend to reach oil-indexed levels during winters to attract flexible cargoes during periods of market tightness. In the last of 2018, the spread between the JCC oil-indexed price and the Asia Spot price was only US$0.30 per MMBtu, but widened to reach a maximum spread of US$6.71 per MMBtu in August 2019 and ended the year at a level of US$4.80 per MMBtu. With spot gas prices reaching record low levels, recent market fundaments have also changed and have been reflected in LNG contractual terms.” (European Commission, 2020)

LNG producers had a very challenging first quarter of 2020 due to the very low natural gas prices. First of all the increase of LNG exports in combination with a mild winter caused a counter-cyclical drop in international natural gas prices. Markets all around the world began to declare lockdowns in order to stop the spread of the COVID-19 virus, and the downward trend persisted throughout the first quarter. China was the first country which announced a lockdown and the results was dramatic for the industries. As the Covid 19's epicenter shifted from China to Europe and the rest of the world, markets throughout the world began to take steps to limit its spread. This resulted in a global slowdown in commercial and industrial activity, which will have a detrimental impact on natural gas and LNG consumption throughout the crisis. The current market climate reduces the likelihood of a price rebound in the near future. (Rystard Energy, 2020)

5.4 Conclusions

While the oil market is integrated globally, the present gas markets are not on this level. Major facts that affect this kind of price divergence is related with differences on pricing mechanisms adopted by each regional market. Typically, there are three main autonomous regions of natural gas markets globally: the European, North American and Asian Market. The first one is mainly supplied by Russia and Africa while the rest are both linked to Middle East. As far as U.S, it follows the gas-on-gas competition with free access to pipeline transportation. The risks deriving from the above-mentioned are usually managed through spot and derivatives markets. Unlike the European region that use long-term contracts linked to oil price and with restrictions to the pipeline access, Asian market rely on long-term contracts benchmark priced to oil. This formation leads to higher LNG prices in Europe and Asia in contrast with other market regions. The current structure of gas markets comes in opposition to the oil one, due to the existence of variations related to the physical characteristics between them. First of all, at normal conditions, oil as a commodity has a high density of temperature and pressure, making it easier for transportation at a reasonable cost. Contrarily, the cost of natural gas transportation composes a crucial fraction of its total delivered cost. Also, it is a fact that natural gas can be replaced with other commodities in industrial process, power generation or even building heat.

Chapter 6: LNG Shipping

6.1 Introduction

The present section is a literature review that focuses on two things. In the beginning presents the LNG transportation through marine sector. After a short description of LNG carriers and their features, it follows a historical analysis of LNG fleet. Starting with the first LNG ship in the world, it ends up with the active LNG fleet of 2020. The orderbook by delivery year and average capacity are presented in this chapter too. The review continues with the analysis of LNG as a marine fuel, the Challenges and opportunities of it and concludes with the Environmental Benefits of LNG Fuel in the maritime industry.

6.2. Historical context

An LNG carrier is a tanker which designed in order to transport liquefied natural gas. The design of LNG ships is considered extremely necessary in order to properly manage the operations of maritime operations. Nowadays huge quantities of LNG are transported via capable LNG ships which are designed thanks to sound research and the rapidly growth of technology.

Figure 5: Methane Pioneer: The First LNG Ship in the World, Marine Insight

(Source: Marine Insight, 2015)

The initial usage of an LNG carrier may be dated back to the late 1950s, when a former cargo ship was converted to be utilized as an LNG ship. As we can see in the picture above (Figure 5), the first LNG ship, the Methane Pioneer, was a milestone moment in the history of freight transport. On January 25, 1959, the Bureau Veritas-classed Methane Pioneer sailed from the Calcasieu River on the Louisiana Gulf coast to the United Kingdom, where the cargo was delivered. Storages of 2.000 tones of capacity which constructed with aluminum were the safer solution in order to transport volatile cargoes. These LNG carriers were be used for many years before it was suitably disposed from active service in the early 1970s. According to Babicz: “Subsequent expansion of that trade has brought on a large expansion of the fleet to today where giant LNG ships carrying up to 266,000 m3 (9,400,000 cu ft) are sailing worldwide.” (Babicz, 2015)

The success of Methane Pioneer prompted the Gas Council and Conch International Methane Ltd. to commission the construction of two purpose-built LNG carriers, the Methane Princess and the Methane Progress. In late 1964, the ships above were outfitted with Conch independent aluminum cargo tanks and joined the Algerian LNG trade. Both Methane Progress and Methane Princess had a capacity of 27,000 cubic meters (950,000 cu ft). (Marine Insight, 2015)

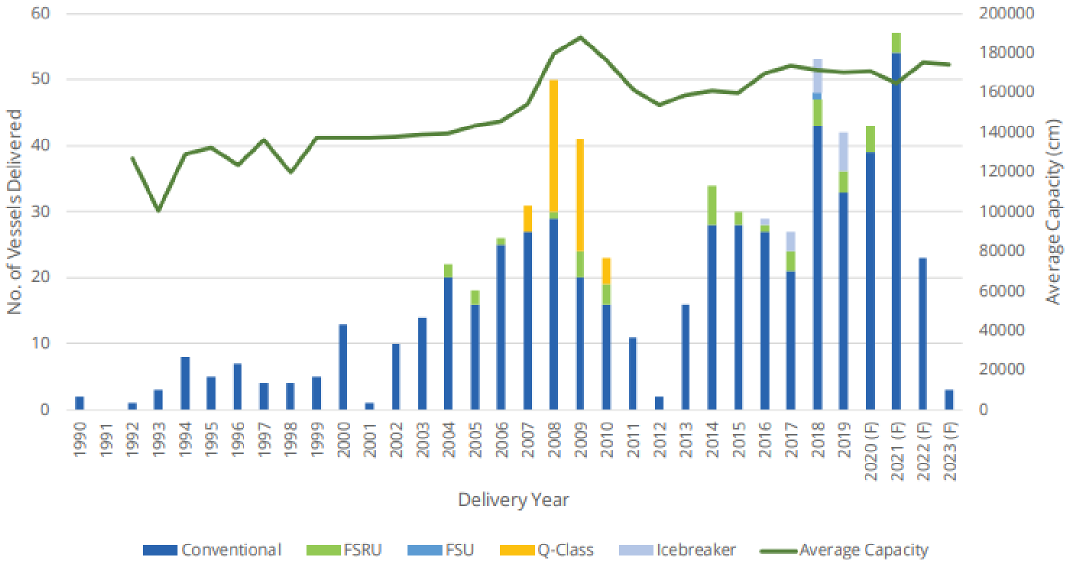
The possibility to export LNG from Alaska's land to Japan came in the late 1960s, and commerce with TEPCO and Tokyo Gas began in 1969. Sweden constructed two ships, the Polar Alaska and the Arctic Tokyo, each with a capacity of 71,500 cubic meters (2,520,000 cubic feet). On Oct. 26, 1969, the brand-new LNG tanker Polar Alaska sailed from Phillips Petroleum's Kenai onloading facility and was routed to Western Japan, bringing the first-ever cargo of LNG to the Japanese market. The ship's landing at a Tokyo Bay receiving dock signified the start of a long and productive partnership between the firm and its Japanese clients. In the early 1970s, the United States government pushed American shipyards to construct LNG carriers, with seventeen LNG ships being constructed in all. The Arctic LNG ships had a significant number of proposals examined towards the end of the 1970s, and at the beginning of the 1980s. (Bullock, 2019)

Nowadays, the size and capacity of LNG carriers shows a great increase. Since 2005, Qatar gas has pioneered the development of two new classes of LNG carriers, the Q-

Flex and the Q-Max. Both of them have a cargo capacity of between 210,000 and 266,000 cubic meters (7,400,000 and 9,400,000 cu ft) and is equipped with a re-liquefaction plant. Since the beginning of 2005, a total of 203 boats have been built, with the worldwide LNG fleet currently consisting of 541 operational vessels, including more than thirty Floating Storage Regasification Units (FSRUs) and four Floating Storage Units (FSUS) (FSUs). Overall, the worldwide LNG fleet increased by 8.4 percent year on year in 2019, with 42 new vessels added, three of which were FSRUs. Furthermore, the annual growth rate of LNG trade in 2019 is 13%, indicating a balance between growth in the LNG transportation industry and growth in LNG trade. (IGU, 2020)

6.3. Global active LNG fleet

Figure 6: Global active LNG fleet and orderbook by delivery year and average capacity



(Source: Rystad Energy, 2020)

It is easy in the figure (Figure 6) above to note that from the beginning of the 2000s, after a general rising trend over the previous decade, the LNG industry has rapidly expanded.

In 2009, just one newbuild LNG carrier was ordered, according to Rex, "because to the global financial crisis in 2008. This resulted in a decrease in delivery until 2013, however since then the market has resumed with deliveries exceeding each year in recent years. The newbuild LNG deliveries continue to rise in the next several years, as seen in the above figure. (Rex, 2018)

According to the worldwide active LNG fleet and orderbook by delivery year and average capacity, it appears that during the previous several years, 86 percent of new builds delivered in 2019 were between 170,000 cm and 180,000 cm in length. Furthermore, more than 90% of the fleet is comprised of young vessels under the age of 20, which is in line with recent advancements and expansion in liquefaction projects. The modern boats are larger and more efficient, with significantly improved project economics during their operating lifetime. In terms of worldwide LNG vessel orderbooks, there were 126 carriers in 2019, accounting for 23.3 percent of the current fleet size of 541 units. This indicates that LNG commerce will continue to rise in the future years, in tandem with the expansion of liquefaction capacity. Another 43 vessels are projected to be delivered through the end of 2020, representing a 7.9% rise in the worldwide fleet total. (IGU, 2020)

6.4 LNG as marine fuel

It is crystal clear that LNG as marine fuel is a potential and an available solution to go along with upcoming air pollution requirements. Also, the use of LNG to supply vessel engines is a tempting commercial solution for new building LNG-fuelled vessels and existing vessels too.

There are three major factors that make LNG a viable alternative choice. To begin with, using LNG as a ship fuel eliminates all SOX and PM pollutants, decreases NOX emissions by up to 90%, and reduces CO2 emissions by 20%. (Herdzik, 2012)

Secondly, a considerable number of ships use LNG in the shipping sector, as LNG carriers use LNG for numerous years. In order to feed their engines, LNG carriers utilize the natural boil-off of LNG stored in their freight tanks. Last but not least, because of its global available nature, LNG as marine fuel is financially advantageous, because LNG reserves can meet the maritime LNG demand in the short term and its cheap prices compared to the primary marine fuel oils that are utilized on board the boats. However, in some regions, the low price of natural gas and LNG in comparison to high sulphur marine fuel oils, such as HFO or IFO, and low sulphur distillates (MDO and MGO), makes LNG an appealing maritime fuel. To date, gas prices in Europe and the United States are much lower than those of high sulphur fuel oils and low sulphur distillates, while LNG prices in Asia are higher than those of high sulphur fuel oils but lower than those of low sulphur distillates. However, it should be noted that natural gas needs infrastructure in order to be liquefied, stored, and delivered to boats. This is the primary reason why is it that a low natural gas price may not be translated into a cheap LNG pricing. However, LNG as a maritime fuel faces significant hurdles, including the development of LNG-fueled engines, LNG handling and storage facilities on board, and LNG bunkering infrastructure. Engines powered by LNG have already been utilized on LNG carriers, but not on other types of vehicles. As a result, according to Aymelek “engine manufacturers have started to develop DF engines capable to burn both LNG and diesel. Furthermore, LNG has to be stored at very low temperature during voyages, for this reason fuel tanks, pipes and handling systems must be fitted with insulation alloys able to keep LNG at the right temperature of -162°C. Finally, port facilities to produce, store and fuel bunkering installations or vessels are required to reliably and operationally supply LNG-fuelled vessels.” (Aymelek et al., 2014).

6.5 Environmental aspects of LNG shipping

Shipping is the most widely utilized mode of transportation on the planet, and it has played a critical role in the growth of the global economy. As a result, vessel emissions are a serious environmental issue because to their influence on environmental degradation, particularly global warming of the atmosphere. Additionally, owing to the world's rising population, it is expected that global seaborne trade will rise in the near future, exacerbating air pollution estimates from marine transport. As a result, the International Maritime Organization (IMO) has created and enacted stricter norms aimed at dramatically reducing vessel emissions. Because CO2, NOX, SOX, and PM are the principal pollutants from vessel engines, these air pollution laws focus on reducing them. New possibilities and solutions have evolved in the shipping sector as a result of the need for boats to adhere to severe emission regulations. Manufacturers have begun to design and develop a wide range of emissions abatement solutions aimed at lowering CO2, NOX, SOX, and PM levels (Semolinos et al., 2013).

Because of its low sulphur content, sophisticated technology, and low price, using LNG as maritime fuel is an appealing and potentially profitable option. LNG as a ship fuel eliminates SOX and PM pollutants while lowering NOX and CO2 emissions. Then, LNG has already been established in the marine industry, with LNG vessels utilizing it for decades. The LNG carriers' engines are powered by the natural boil-off of the LNG stored in their cargo tanks. Nonetheless, LNG-powered tankers require technical advancements to find solutions in LNG combustion, handling, and storage, which have enabled it to become a viable alternative explored by ship owners (Adamchak & Adede, 2013).

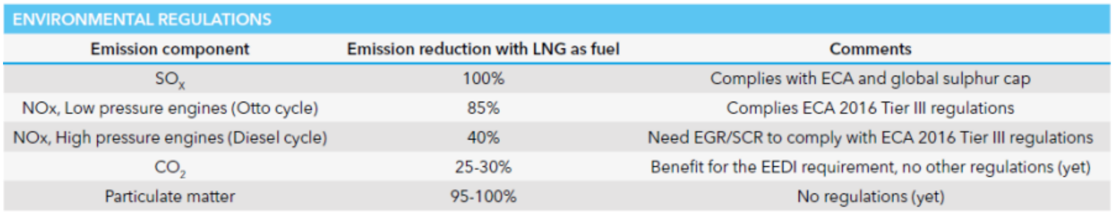
Finally, LNG's economic appeal as a maritime fuel is based on its low cost. Natural gas, and hence LNG, has been comparatively cheaper than low sulphur distillates, marine diesel oil (MDO), and marine gas oil (MGO), as well as high sulphur marine fuel oils, heavy fuel oil (HFO), and intermediate fuel oil (IFO), in recent years, according to records of marine fuel costs. Furthermore, LNG reserves sufficient to meet future LNG demand from the maritime sector contribute to the use of LNG in vessel engines.

However, the pricing of marine fuels are affected by a number of external factors, resulting in changing costs and making it impossible to create reliable price estimates and evaluations. Furthermore, the scarcity of LNG bunkering infrastructure is the biggest drawback of LNG as a ship fuel, since there are only a few LNG plants in the Baltic and North Sea areas, and therefore no unified LNG supply chain along international trade routes has been built. (Wan et al., 2018).

6.5.1 Environmental Benefits of LNG Fuel as maritime fuel

LNG fuel is one of the cleanest-burning fuels available across the entire emission spectrum. A low-pressure engine can reduce NOx emissions by up to 85 percent and a high-pressure engine can reduce them by up to 40 percent, according to the data in the table 4. LNG also has the potential to reduce CO2 emissions by up to 30 percent when used in conjunction with a low-pressure engine. The use of NOx reduction technology such as selective catalytic reduction (SCR) or exhaust gas recirculation (EGR) systems in certain LNG-capable engine designs may be required; however, some 4-stroke (low-pressure) engines can meet Tier III NOx requirements without the use of such technology.

Table 4: Environmental Benefits of LNG Fuel



ENVIRONMENTAL REGULATIONS

Emission component	Emission reduction with LNG as fuel	Comments
SO_X	100%	Complies with ECA and global sulphur cap
NOx, Low pressure engines (Otto cycle)	85%	Complies ECA 2016 Tier III regulations
NOx, High pressure engines (Diesel cycle)	40%	Need EGR/SCR to comply with ECA 2016 Tier III regulations
CO_2	25-30%	Benefit for the EEDI requirement, no other regulations (yet)
Particulate matter	95-100%	No regulations (yet)

(Source: DNV GL October 2015)

As previously stated, the two most important NOx reduction technologies are selective catalytic reduction (SCR) and exhaust gas recirculation (EGR). Urea is introduced into the stack, where it reacts with exhaust on the surface of a catalyst, resulting in the operation of SCR technology (typically titanium or vanadium oxides). The fact that the exhaust reacts outside of the combustion process means that engine efficiency is not compromised, but operational costs are increased. When used with two-stroke engines, EGR technology recirculates exhaust back through the combustion chamber, lowering the overall combustion temperature and resulting in a reduction in NOx emissions of 70-80%. However, these systems do not directly address SOx and PM, but rather use a water treatment process in addition to the scrubber, which increases the total cost of ownership. SCR technology is the most likely solution for achieving Tier III compliance with 4-stroke engines, whereas SCR or EGR technology can be used with 2-stroke engines that burn fuel oil or low sulfur distillates to achieve Tier III compliance. LNG, on the other hand, is a Tier III solution that does not necessitate the use of an SCR or an EGR. (Nishifuji 2017).

Low sulfur distillates, including marine gasoil (MGO), will be the most likely choices for meeting SOx emission standards in the future. This fuel type, on the other hand, has a number of disadvantages when used in current engines, including reduced viscosity, worse lubrication, lower flash and volatility points, and higher sediment buildup in the cylinder, among other things. While there are a variety of options for addressing these challenges, the installation of exhaust gas cleaning systems (EGCS), often known as scrubbers, has emerged as the preferred alternative for shipowners. While scrubbers have relatively expensive capital expenditures (about $5 million), they can reduce sulfur content of emissions to the equivalent of utilizing 0.1 percent sulfur fuel oil, which is compliant with the ECA limit, while also decreasing particulate matter by 70-80%. Water-based and dry scrubbers are the two types of scrubbers available. Wet scrubbers clean exhaust gas using treated water and are available in open, closed, and hybrid loop configurations, whereas dry scrubbers employ a reactant such as sodium or calcium hydroxide to remove SOx from the air. Wet scrubbers are more readily accessible, but both types contribute considerable CAPEX and OPEX to a shipowner's bottom line, particularly when it comes to waste processing and disposal.

Overall, scrubbers may be the most cost-effective option in a climate when fuel oil prices are low and distillate prices are high. In the meantime, if LNG-capable engines, fuel systems, and bunkering networks become more widely available, LNG fuel may rise in market share as a result of its economic competitiveness and environmental advantages. (Nishifuji 2017).

Last but not least, LNG-capable boats are also significantly more competitive in terms of lowering greenhouse gas emissions. LNG fuel has the potential to reduce CO2 emissions by as much as 25-30 percent. Dual-fuel engines, on the other hand, are plagued by a problem known as 'methane slip,' which is a flaw in the Otto cycle that permits methane to escape via the exhaust system unburned. Because methane has a larger global warming potential than carbon dioxide, unchecked methane leak can cancel out the benefits of LNG-capable vessels in terms of GHG reduction. Engine manufacturers like as Wärtsilä have made considerable advancements in their direct injection (DF) engine designs, reducing methane slip to less than 6g/kWh, a level that is considered competitive with alternative fuels. (Ship and Bunker 2016).

6.6 Conclusions

It is the focus of this chapter to emphasize how important shipping has been in the development of LNG. Research and investment have opened the way for LNG ships that are specifically designed and capable of transporting large amounts of liquefied natural gas, dating back to 1950 when the first LNG carrier was utilized to transport liquefied natural gas. There are now more than 500 LNG vessels in operation in the world's LNG fleet. Therefore, LNG commerce will continue to rise in the near future in conjunction with the increase in liquefaction capacity.

To summarize, liquefied natural gas as a marine fuel is economically attractive due to its widespread availability, which will be sufficient to fulfill future LNG demand from the maritime transport industry, as well as its low price when compared to alternative marine fuel oils utilized on board vessels. Last but not least, LNG as a maritime fuel is a practical and easily available solution to the problem of looming air pollution regulations that must be met in the future.

Chapter 7: Conclusions

It is clear that in recent decades, natural gas has tended to become the fastest growing energy source in the global market, and it is widely available. It is extremely significant that gas is the cleanest burning petroleum based fuel, since its CO2 emissions are lower than all other derivative petroleum fuels. In that way, the use of LNG has been instrumental in lowering emissions and improving air quality. In comparison to oil, the market share of natural gas is much smaller because of transportation's obstacles that gas has to deal with them. This is one of the main reasons that attention has shifted to a more efficient way of transferring natural gas, and that is through its liquefaction and transportation via the marine sector. Another parameter which comes into play when enhancing the role of LNG is the geopolitical and geographical constraints on global gas supply. To make LNG available for use in a country, governments and companies have invested in a number of different facilities that are highly linked and dependent upon each other.

Furthermore, the current thesis examines LNG imports and exports from nations that constitute the international LNG trade. It presents the largest global LNG trade flow routes. The international LNG trade continues to experience significant growth and diversification and has done so for the past few years. Such growth will require continuous huge capital investments along the global LNG supply chain. In recent decades, a remarkable number of the largest gas companies have directed their interest in huge investments in order to expand their LNG facilities. What is more, they invest in new LNG projects regarding LNG trading through shipping transportation. Both newcomers and a number of traditional gas producers and consumers have started to be encouraged to invest in the market thanks to the flexibility and benefits that LNG businesses offer. In this way, LNG development is starting to grow faster in comparison with gas pipelines.

At this point, after the study of chapters 3 and 4, it is easily visible that the development of LNG investments affects positively the economic growth of nations that own LNG fleets and terminals, as they determine LNG pricing at a significant rate. Qatar, Australia, the United States, and Russia are the top four exporting countries in the world. As a result, the above gas exporters determine the gas pricing through the different price regimes that they follow. Gas pricing is also affected by the LNG importers.

It is clear that the Asian regions possess the greatest amount of regasification capacity of any markets on a global level. The markets with the largest regasification capacity are Japan, Korea and China. European markets are close behind, accounting for roughly 20% of total global regasification capacity. In this way, they achieve effective coverage of the current and future energy needs of their country with an environmentally friendly resource.

Last but not least, the rise in gas usage percentage is the potential solution to the environmental threats posed by other fuels such as coal and oil. There are many reasons that natural gas is considered a sustainable choice for the planet. First and foremost, natural gas is the cleanest fossil fuel of all, thanks to its simple chemical composition. Furthermore, in comparison with other forms of energy such as coal or oil, natural gas produces fewer impurities, which, as a result, contributes to a decline in the greenhouse effect, acid rain, and other kinds of pollution. At this point, it is important to underline that nations are making significant efforts to contribute to dealing with climate change under the prism of the Paris Agreement.

The present thesis paves the way for further study of some subjects that are not investigated deeper in this thesis, such as the importance of LNG fleet and terminal development in order to face the obstacles of LNG transportation to every possible aspect of the continent.

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